

ARGONNE NATIONAL LABORATORY
CENTER FOR NANOSCALE MATERIALS
and
CHEMISTRY DIVISION SEMINAR

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TITLE: *Near-field Magneto-photoluminescence
and Optical-fiber-induced Stress
Experiments on Quantum Dots in III-V
Semiconductor Compounds*

DATE: Wednesday, April 9, 2003

TIME: 2:00 pm

PLACE: CHM, Bldg. 200, Room J183

HOST: Gary Wiederrecht

Near-field magneto-photoluminescence and optical-fiber-induced stress experiments on quantum dots in III-V semiconductor compounds

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In this talk I describe a set of experiments using near-field optical microscopy to investigate quantum confinement of electronic particles in a variety of semiconductors. Low temperature magneto-photoluminescence has been employed to determine the size, density, and relative composition of quantum dots for several III-V semiconductor systems. The binding energies of electronic particles in these quantum-confining structures can be determined from these measurements. In addition, we find that we are able to apply uniaxial stress in a reproducible manner to systems of self-assembled quantum dots (SAQDs), simply by “pushing” the tip of the near-field optical fiber against the surface of the epitaxial-layer sample containing these dots, and measuring the photoluminescence in excitation/collection mode.

Two sets of experiments will be reported. In the first, we have investigated the ternary and quaternary narrow bandgap materials $\text{In}_x\text{Ga}_{1-x}\text{As}_{1-y}\text{N}_y$ containing dilute concentrations of N (up to 5%), and either 0% or 8% In [1]. These alloys have recently attracted considerable attention as promising materials for optical devices at 1.3 & 1.5 μm . We use near-field magneto-photoluminescence to study optical and structural properties of quantum-dot-like compositional fluctuations in these alloys.

Secondly, experimental and theoretical investigations of high-energy shifts of single InAs, InGaAs, InAlAs and InP quantum dot (QD) emission lines induced by contact pressure exerted by a near-field optical fiber tip are reported. “Pressure” coefficients of 0.65-3.5 meV/nm have been measured for ground state emission lines in agreement with numerical calculations.

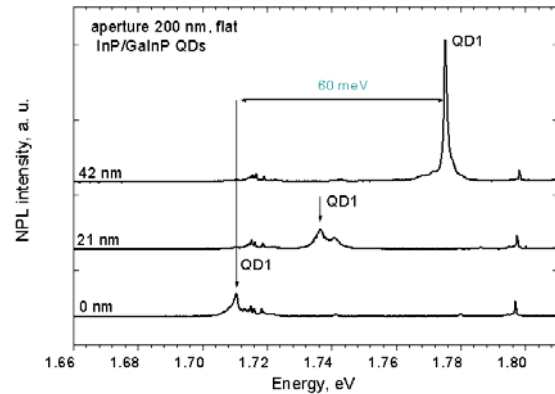
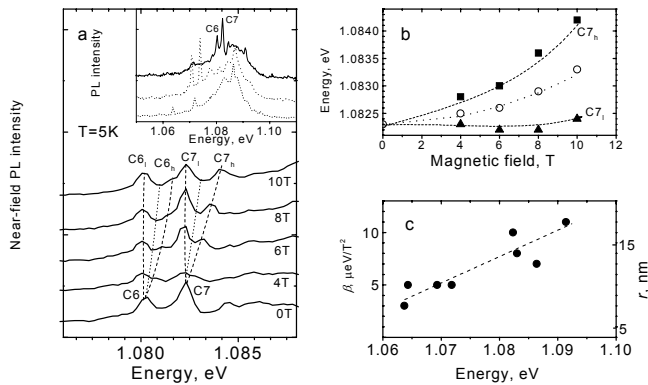
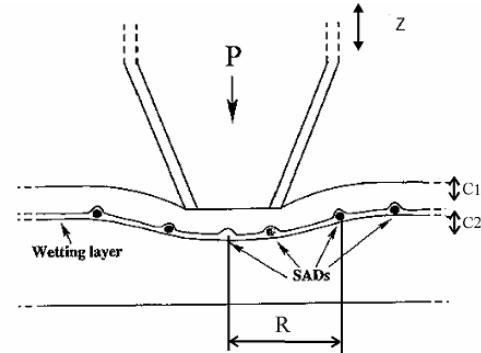
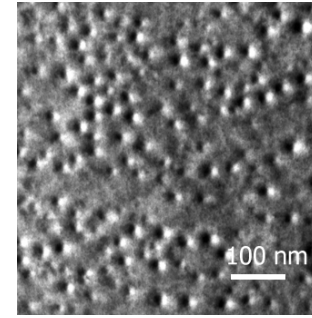
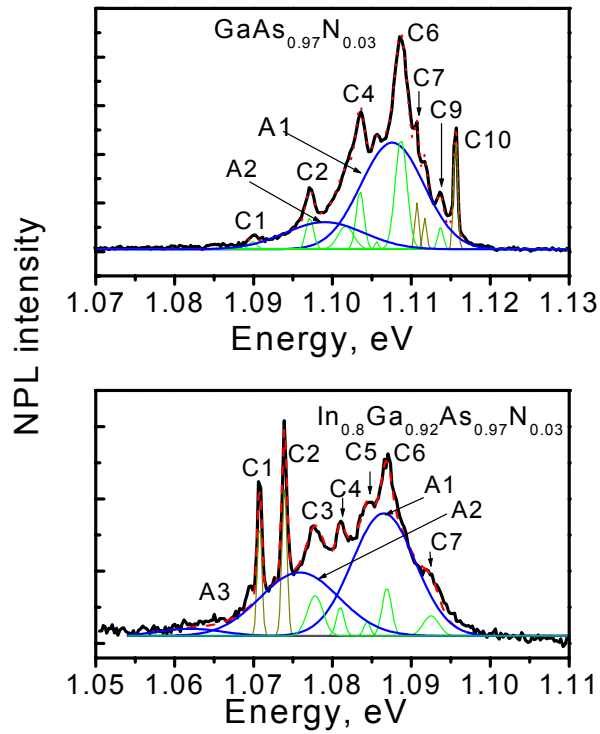


Fig. 1: Top shows near-field photoluminescence (NPL) of GaAsN and InGaAsN. Curves A are regions of weak localization, lines C are quantum dots. Bottom shows Zeeman splittings with increased magnetic field, and size of quantum dots extracted from the diamagnetic shift of these splittings.

Fig. 2: Top is a typical QD sample (InAs/AlAs). Middle is a “cartoon” showing the application of stress with the near-field fiber tip [2], which is simultaneously used to excite and collect emission. Bottom shows significant increase in luminescence energy and intensity for InP QDs in GaInP.

References:

1. A.M. Mintairov, T.H. Kosel, J.L. Merz, P.A. Blagnov, A.S. Vlasov V.M. Ustinov, and R.E. Cook, “Near-field magneto-photoluminescence spectroscopy of composition fluctuations in InGaAsN”, Physical Review Letters **87**, 277401 (31 December 2001).
2. H.D. Robinson, M.G. Müller, B.B. Goldberg, and J.L. Merz, “Local Optical Spectroscopy of Self-Assembled Quantum Dots Using a Near-Field Optical Fiber Probe to Induce a Localized Strain Field”, Appl. Phys. Lett. **72** (17), 2081-2083 (27 April 1998).